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Research Article

The long-term effect of repeated exposure to degraded nature via immersive virtual reality on environmental awareness and pro-conservation behavioral intention: A longitudinal approach

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Abstract

Immersive virtual reality is increasingly being used as a tool for promoting environmental awareness, particularly to strengthen engagement with nature. However, most research has focused on the short-term effects of a single exposure, neglecting the issue of sustainability and the potential reinforcement of effects through repeated exposure. Furthermore, few studies have examined the role of affective factors such as love and care for nature in this context. The aim of this study was to examine short- and long-term differences in levels of environmental awareness and pro-conservation behavioral intention, depending on repeated (vs. single) exposure to immersive VR depicting degraded nature environments, taking into account love and care for nature as moderators. A laboratory experiment was conducted with 171 students randomly assigned to conditions of single or repeated exposure to immersive virtual reality. Data was collected at two separate times: immediately after exposure and two months later. The results indicate that, in the long term, environmental awareness varies depending on the exposure type, with higher levels observed after repeated exposure compared to a single exposure. However, no significant difference was observed for pro-conservation behavioral intention. Environmental awareness appears to fully mediate the relationship between exposure type and pro-conservation behavioral intention. Finally, the results indicate that love and care for nature positively moderate the relationship between environmental awareness and pro-conservation behavioral intention. Nevertheless, it should be emphasized that, in the absence of pre-test measurement of the dependent variables, an intervention effect, in the strict sense, cannot be determined.

Key words: Immersive virtual reality, repeated exposure, environmental awareness, pro-conservation behavioral intention, love and care for nature

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Introduction

Human behavior plays a central role in current major environmental challenges, such as climate change, deforestation and biodiversity loss (Ripple et al. 2017). Encouraging environmentally friendly behavior on a large scale could contribute significantly to mitigating these environmental problems (Yu et al. 2023). Among the strategies proposed to promote such behavior, exposure to nature,

whether real or mediated, seems to offer promising prospects (Klein and Hilbig 2018; Yu et al. 2023). A substantial number of studies have shown that contact with nature generates various psychological and social benefits (Bratman et al. 2019; Yu et al. 2023), which could strengthen appreciation for natural environments and, in turn, encourage their protection (Lange and Truyens 2022; Yu et al. 2023). Nevertheless, in a context marked by increasing urbanization and generalized digitalization, the time spent by individuals in natural environments is steadily decreasing (Soga and Gaston 2016; Klein and Hilbig 2018). To palliate this decline in direct contact with nature, researchers have turned to innovative digital solutions, such as immersive technologies, to recreate the experience of nature. Virtual reality (VR), in particular, has been used to design immersive environments that simulate real natural scenes (Yu et al. 2023). One of the advantages of VR is its ability to generate digital environments that are both immersive and interactive, giving users a strong sense of 'presence', i.e. the subjective impression of being physically located within the virtual environment (Waterworth et al. 2015). This sensation is greatly amplified by the use of head-mounted displays (HMDs), which immerse the user by partially or totally isolating them from their real environment and occupying a large portion of their field of vision. By providing a consistent and continuous sensory perception of three-dimensional spaces, these devices contribute to increased immersion and a more engaging user experience (Thoma et al. 2023).

Several studies indicate that viewing unspoiled natural landscapes can promote environmental engagement, particularly by reinforcing pro-environmental attitudes and intention to act in favor of environmental protection (Zelenski et al. 2015; Ibanez and Roussel 2022). However, these results are not unanimous, with some studies finding no significant effect of this type of exposure (Klein and Hilbig 2018; Lange and Truyens 2022). This divergence suggests that simply being exposed to unspoilt landscapes is not always enough to prompt action and may, in some cases, induce a sense of complacency or the impression that the environmental situation does not require immediate intervention (Klein and Hilbig 2018). In contrast, exposure to degraded natural environments seems more likely to provoke a sense of urgency by highlighting the consequences of human activities on ecosystems, thereby encouraging more environmentally responsible behavior (Klein and Hilbig 2018; Yu et al. 2023).

While immersive VR is widely recognized as a promising approach for raising awareness of environmental issues (Thoma et al. 2023; Nouri and Bouzaabia 2025; Nouri et al. 2025), most existing research is based on single exposures and mainly uses traditional media, such as images or videos, which limits our understanding of the potential effects of repeated exposure. Moreover, the long-term effects of repeated exposure to this technology remain largely understudied, (Frechette et al. 2023), particularly in the environmental field. Most research has been limited to studying the long-term effects of a single exposure to immersive VR (Huang and Yang 2022; Huang et al. 2025; Lukander et al. 2025), which can lead to undesired effects such as cybersickness (Nouri et al. 2025). The feeling of cybersickness corresponds to a form of motion sickness induced by incongruous visual stimuli when exposed to a virtual environment, resulting in physiological and perceptual symptoms such as spatial disorientation and nausea (LaViola 2000). Some studies suggest that repeated exposure could allow users to become habituated to the VR sensation and thus help mit-

igate the undesired effects (Palmisano and Constable 2022). Nevertheless, to the best of our knowledge, these studies have mainly focused on technological tolerance, leaving the potential effects of repeated exposure on environmental psychological or behavioral variables largely understudied. Furthermore, some previous researches have suggested that an individual's emotional connection to nature could play a decisive role (Otto and Pensini 2017; Soga and Gaston 2024), and that the relationship between contact or exposure to nature and conservation behaviors may be moderated by factors such as this affective connection to nature (Martin et al. 2020). Therefore, love and care for nature may play a decisive role in the effect of environmental awareness on pro-conservation behavioral intention. It is likely that people who feel a strong sense of love and care for nature are more likely to translate their environmental awareness into concrete actions, adopting sustainable pro-environmental behaviors and being motivated to actively contribute to nature conservation. In this perspective, the present research aims to examine differences in levels of environmental awareness and pro-conservation behavioral intention, measured immediately and two months after repeated (vs. single) exposure to immersive VR experience representing degraded nature environments, taking into account love and care for nature as a moderating variable. Given these aims, this study seeks to answer the following research questions:

- Does immersive VR exposure type (repeated vs. single) lead to differences in environmental awareness and pro-conservation behavioral intention immediately after exposure and two months later?
- Do love and care for nature moderate the effect of environmental awareness on pro-conservation behavioral intention?

Literature review and hypotheses development

VR appears to be a promising alternative to direct experiences with nature (Spangenberger et al. 2024). It represents a particularly immersive alternative to traditional approaches due to its ability to immerse users in simulated environments (Slater 2018). This type of immersion promotes the emergence of a stronger sense of presence, i.e. the subjective perception of actually being present in the virtual environment (Slater 2018; Spangenberger et al. 2024).

Unlike non-immersive VR, immersive VR incorporates features that greatly enhance the sense of physical presence in a simulated environment (Kandaurova and Lee 2019). This feeling of "presence" makes virtual experiences more realistic and authentic (Wieland et al. 2024) and is a key factor in the effectiveness of immersive VR compared to non-immersive digital experiences. From a psychological perspective, immersive VR acts by reducing the psychological distance from the phenomena being studied. It decreases temporal distance by allowing users, for example, to experience the future consequences of climate change as if they were happening in the present (Trope and Liberman 2010). It also reduces spatial distance by making it possible to perceive distant places as if they were actually present. This reduction in psychological distance makes abstract concepts, such as environmental degradation and climate change, more immediate and tangible (Kleinlogel et al. 2023). Furthermore, sensory immersion and real-time interaction allow users to feel environ-

mental impacts, reinforcing their motivation to take action (Nouri et al. 2025). In comparison, non-immersive VR, limited to conventional interfaces such as a screen or 360° video, does not produce the same intensity of presence, reducing its potential to raise awareness of environmental issues (Thoma et al. 2023). Numerous previous studies, in various contexts such as climate change and environmental degradation, have shown that immersive VR is a particularly effective tool for raising awareness of environmental issues (Markowitz and Bailenson 2021; Thoma et al. 2023; Nouri et al. 2025), as well as promoting and encouraging the adoption of pro-environmental behaviors (Klein and Hilbig 2018; Breves and Heber 2020; Plechatá et al. 2022). For example, Thoma et al. (2023) and Nouri et al. (2025) demonstrated that exposure to immersive VR depicting the melting of the Aletsch Glacier constitutes a more effective awareness-raising tool than non-immersive VR for promoting awareness of climate change issues. Plechatá et al. (2022) observed that exposure to VR content on dietary footprints strengthens students' intention to adopt more environmentally friendly behaviors. Moreover, Breves and Heber (2020) demonstrated that exposure to immersive 360° nature videos increases participants' motivation to adopt pro-environmental behaviors. Similarly, the study conducted by Klein and Hilbig (2018) highlighted that exposure to immersive scenes of degraded nature has a particularly marked effect on individuals, suggesting that media representations of ecosystem deterioration are more effective in encouraging pro-environmental behavior. By making the consequences of environmental damage visible, these representations help to reinforce the perception of urgency and highlight the need for immediate action to protect the environment. In the same vein, Yu et al. (2023) show that exposure to degraded natural environments encourages participants to become more engaged and make greater efforts to protect the environment.

Recent studies on immersive VR show a clear distinction between its short-term and long-term effects depending on the context of application. In the field of health, Huang and Yang (2022) found that immersive VR depicting historical type of residence that was commonly found throughout Taiwan provides immediate emotional benefits for patients with dementia, but that its effects on maintaining cognitive abilities decline over time in the absence of further sessions. A subsequent study by Huang et al. (2025) confirms these trends, showing that a one-month immersive VR intervention featuring culturally familiar Taiwanese locations improves neuropsychiatric symptoms and reduces caregiver burden, with some symptom improvements lasting for two months. In the field of education, Pande et al. (2021) observed that, compared to a pre-recorded video, immersive VR simulating three environmental biology topics (pigment extraction, food web structure, and biodiversity) immediately promotes student engagement, motivation, and conceptual understanding, while its long-term effects result in sustained knowledge retention, although the novelty effect tends to diminish over time. Moreover, the study by Lukander et al. (2025) shows that immersive VR applied to training for occupational safety has positive short- and long-term effects. High interactivity during training immediately improves participants' perception of control and motivation, while promoting proactive safety behaviors and better integration of best practices in the long term. Finally, Ahn et al. (2014) showed that the embodiment of tree cutting in immersive VR induces a higher internal locus of control and environmental behaviors than

those observed after exposure to printed or video messages one week after the experiment. Overall, this research indicates that immersive VR has different effects depending on the time frame and context of application. In the short term, it is a powerful lever for emotional, motivational and attentional stimulation, promoting immediate engagement. In the long term, its benefits depend on continuous exposure. Thus, when VR is used repeatedly, it can support knowledge consolidation and lasting behavioral change. However, in the absence of re-exposure, the effects tend to diminish, suggesting that immersive VR should be considered as an integrated and recurring tool rather than a single intervention. Therefore, it is reasonable to propose that, in the long term, differences might be observed in environmental awareness and pro- conservation behavioral intention, with potentially higher levels after repeated exposure to immersive VR than after a single exposure. Consequently, the following hypotheses are formulated:

1. H1: Participants exposed to repeated immersive VR experiences will report higher levels of environmental awareness two months after exposure than those exposed to a single immersive VR experience.
2. H2: Participants exposed to repeated immersive VR experiences will report stronger pro-conservation behavioral intention two months after exposure than those exposed to a single immersive VR experience.

Numerous studies have shown that environmental awareness is a key determinant of environmentally friendly intentions and behaviors (Dornhoff et al. 2019; Lin et al. 2022). For example, Ari and Yilmaz (2017) showed that this awareness has a positive influence on individuals' willingness to adopt environmentally friendly actions. Yang et al. (2021) confirmed this beneficial effect by demonstrating the close link between environmental awareness and pro-environmental behaviors. Moreover, Dornhoff et al. (2019) highlighted that awareness of biodiversity loss has a positive influence on the adoption of behaviors that promote biodiversity conservation. Finally, Lin et al. (2022) emphasized that, in the tourism and hospitality sectors, environmental awareness significantly promotes individuals' pro-environmental behavioral intentions. Therefore, the following hypothesis is formulated:

3. H3: Environmental awareness positively influences pro-conservation behavioral intention.

Contemporary environmental issues are profoundly linked to the relationship that human beings have with nature (Kosta et al. 2022). Numerous studies indicate that individuals who feel a strong connection to nature are more likely to adopt pro-environmental attitudes and behaviors (Frantz et al. 2005; Nisbet et al. 2009). The concept of love and care for nature is defined as "deep love and caring for nature which includes a clear recognition of nature's intrinsic value as well as a personal sense of responsibility to protect it from harm" (Perkins 2010). Soga and Gaston (2024), in their meta-analysis, suggested that emotional connection with nature may constitute a determining factor for pro-environmental behavior. Consistently, other research indicates that the relationship between exposure to nature and pro-environmental behavior is not necessarily

direct, but may be mediated by affective dimensions, such as emotional feelings towards nature (Otto and Pensini 2017). Although the majority of previous studies have treated the emotional connection with nature as a mediator—that is, exposure to or contact with nature strengthens this emotional connection, which in turn leads to positive effects on pro-environmental behavior (Mayer et al. 2009; Otto and Pensini 2017; Whitburn et al. 2019), this study focuses on the moderating role of love and care for nature. Indeed, it has been argued that individuals who feel an integral part of nature are less inclined to harm it, as any environmental damage is perceived as personal damage (Mayer and Frantz 2004). Furthermore, Martin et al. (2020) demonstrated that nature connectedness moderates the relationship between contact with nature and certain measures of pro-environmental behavior. Consequently, it is plausible that the level of love and care for nature moderates the relationship between environmental awareness and pro-conservation behavioral intention. Based on these studies, the following hypothesis is formulated:

4. H4: Love and care for nature positively moderate the effect of environmental awareness on pro-conservation behavioral intention.

The research framework is illustrated in Fig. 1.

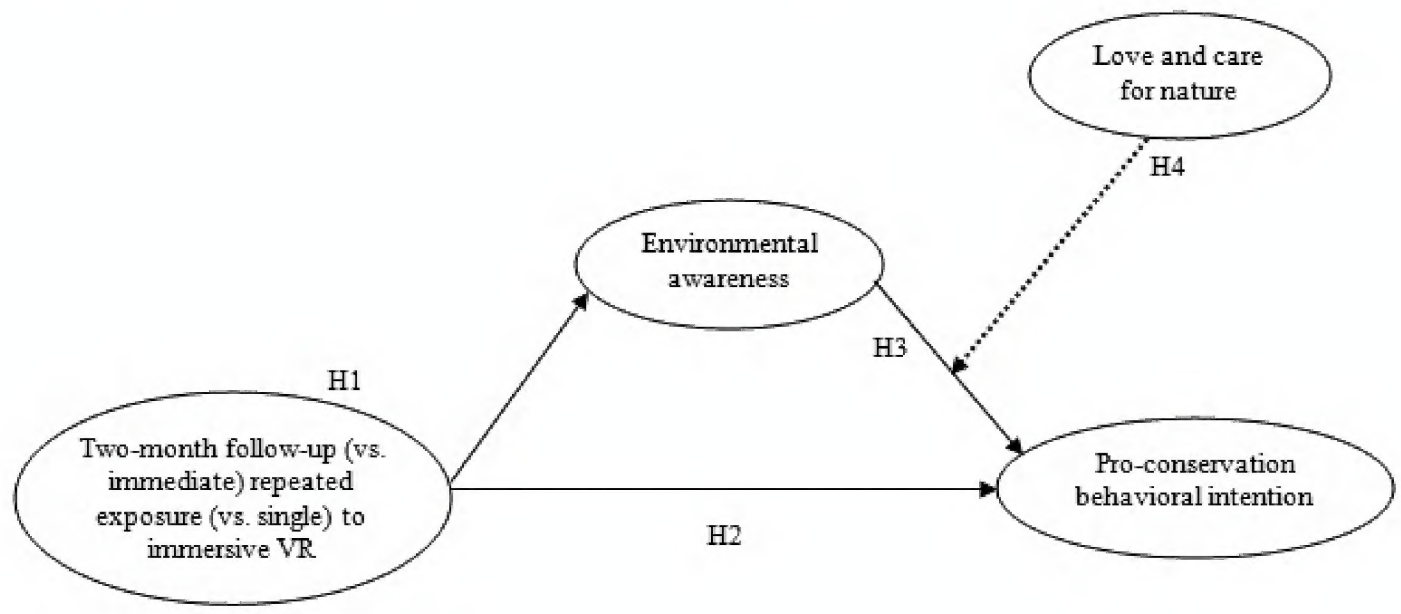

Figure 1. Conceptual model.

Methodology

Design and procedure

In order to achieve the objectives of this research, a 360° video consisting of artificial/simulated footage was specially designed for this study. All participants viewed the same video, showing degraded natural environments such as a beach overrun with plastic waste, deforested forests giving way to arid soil, natural landscape invaded by mists of atmospheric pollution, as well as drained wetlands, once rich in biodiversity. These sequences provide a striking illustration of the visible consequences of human activity on nature, while underlining the urgent need to take action to preserve it.

In addition, to examine the long-term (vs. immediate) effects of repeated exposure (vs. single exposure) to immersive VR, a laboratory experiment was conducted using a between-subjects design, based on the manipulation of the type of exposure (single vs. repeated). Participants in this study were university

students, recruited on a voluntary basis via advertisements on the university's internal networks (targeted mailing lists, student Facebook groups, etc.). They were invited individually to the laboratory, with the possibility of choosing their time slot in order to ensure maximum flexibility, limit logistical constraints and minimize waiting times. On arrival, participants were welcomed and informed that their participation was entirely voluntary, that their data would be treated as strictly confidential and anonymous, and that they could withdraw from the experiment at any time. Before being exposed to the experimental conditions, participants provided their informed consent verbally. They were then randomly assigned to one of the two experimental conditions by drawing lots using two opaque cards placed face down: one marked 'single exposure', the other 'repeated exposure'. Each participant drew a card themselves, ensuring an impartial and transparent process.

In the single exposure condition, participants were exposed to the 360° video once and then immediately completed a questionnaire assessing their environmental awareness and pro-conservation behavioral intention. In the repeated exposure condition, participants viewed the 360° video four times, with a regular interval of 24 hours between each session. They then completed the questionnaire immediately after the last session. Finally, whatever the experimental condition, all participants were invited two months later to complete a final questionnaire assessing their environmental awareness, their pro-conservation behavioral intention, and their feelings of love and care for nature.

Measures

"Environmental awareness" was assessed using the scale developed by Trivedi et al. (2018), a seven-point Likert scale with four items, ranging from 1 ('strongly disagree') to 7 ('strongly agree'). "Pro-conservation behavioral" intention was measured with 3 items developed by Jacobs and Harms (2014) and adapted by Straka et al. (2025). These items assess participants' intention to engage in conservation actions, using a 7-point Likert scale ranging from 1 = very unlikely to 7 = very likely. These two scales were administered immediately after exposure and two months later. "Love and care for nature" was measured using the scale of Perkins (2010), a seven-point Likert scale consisting of 15 items, ranging from 1 ('strongly disagree') to 7 ('strongly agree'). This scale was administered only two months after exposure to the experimental conditions. All items are presented in Table 1.

Statistical analyses

In order to assess the reliability and validity of the measurement scales used in this study, a confirmatory factor analysis (CFA) was conducted using AMOS 22 software. The internal reliability of the constructs was examined using composite reliability (CR), the value of which must exceed 0.60 to be considered acceptable (Hair et al. 2010). Convergent validity was assessed using the average variance extracted (AVE), which must be greater than 0.50 to be considered satisfactory (Fornell and Larcker 1981). Moreover, to test the research hypotheses, two mixed ANOVA analyses and a moderated mediation analysis using the PROCESS macro (model 14, with 5,000 bootstraps) were performed using

Table1. Measurement items.

Environmental awareness (Trivedi et al. 2018)
EA1: I believe that humanity is seriously abusing the environment
EA2: I think that humans produce disastrous consequences in nature
EA3: I consider that the balance of nature is very delicate and easily upset
EA4: I think that one must live in harmony with nature in order to survive
Pro-conservation behavioral intention (Jacobs and Harms 2014)
PCBI1:Volunteer more for nature protection
PCBI2: Motivate family and friends to volunteer more for animal and plant species
PCBI3: Inform myself about nature protection, the environment, animals and plants
Love and care for nature (Perkins 2010)
LCN1: I feel joy just being in nature
LCN2: I feel that closeness to nature is important for my wellbeing
LCN3: When I am close to nature, I feel a real sense of oneness with nature
LCN4: I feel content and somehow at home when I am in unspoilt nature
LCN5: I feel a deep love for nature
LCN6: I often feel emotionally close to nature
LCN7: When I spend time in unspoilt nature I feel that my day-to-day worries seem to dwindle away in the face of the wonder of nature
LCN8: Protecting the wellbeing of nature for its own sake is important to me
LCN9: I feel spiritually bound to the rest of nature
LCN10: I feel a personal sense of interconnectedness with the rest of nature
LCN11: I often feel a sense of awe and wonder when I am in unspoilt nature
LCN12: I often feel a strong sense of care towards the natural environment
LCN13: I need to have as much of the natural environment around me as possible
LCN14: When in natural settings I feel emotionally close to nature
LCN15: I enjoy learning about nature

SPSS 22. Given that the objective of this study is to examine the immediate and long-term effect of single or repeated exposure to immersive VR experiences depicting scenes of degraded nature, the use of mixed ANOVA is particularly relevant. This type of analysis makes it possible to study the effect of several factors on a quantitative dependent variable in designs combining repeated measurements in the same participants (within-subject factors) and independent groups (between-subject factors). Composite scores for environmental awareness and pro-conservation behavioral intention were calculated by averaging the items corresponding to each construct and were used as dependent variables in the analyses. Mixed ANOVA thus makes it possible to examine the main effect of the between-subject factor (Exposure type to immersive VR: single vs. repeated), testing the differences between groups, the main effect of the within-subject factor (Time: immediately after exposure vs. two months later), indicating the evolution of scores over time, and the interaction effect between these factors, revealing whether the evolution of scores differs between groups. Furthermore, the use of the PROCESS macro, model 14, is justified by the desire to test the relationship between environmental awareness and pro-conservation behavioral intention (H3), as well as the moderating role that love and care for nature may play in this relationship (H4). This approach is based on a bootstrap procedure, which allows the confidence intervals of indirect effects to be estimated without assuming the normality of their sampling distribution, in contrast to the Sobel test (Hayes 2018).

Results and discussion

Demographic profile

A total of 174 students participated in the study. However, one participant discontinued their participation due to cybersickness, and two others were unable to complete the final assessment, conducted two months later, due to health problems (Fig. 2). The demographic characteristics of the 171 participants who completed the study indicate an average age of 26.72 years, with 53.8% women and 46.2% men. Regarding the educational level, participants were mainly divided between three university cycles: the majority were enrolled in bachelor's degrees (47.4%), followed by master's students (32.7%) and doctoral students (19.9%).

Confirmatory factor analysis

The results, presented in Table 2, indicate that all scales demonstrate satisfactory internal reliability and validity, with composite reliability indices above 0.60 (Hair et al. 2010) and average extracted variance values above 0.50 (Fornell and Larcker 1981), attesting to the psychometric robustness of the measurement scales used, justifying their use in subsequent statistical analyses.

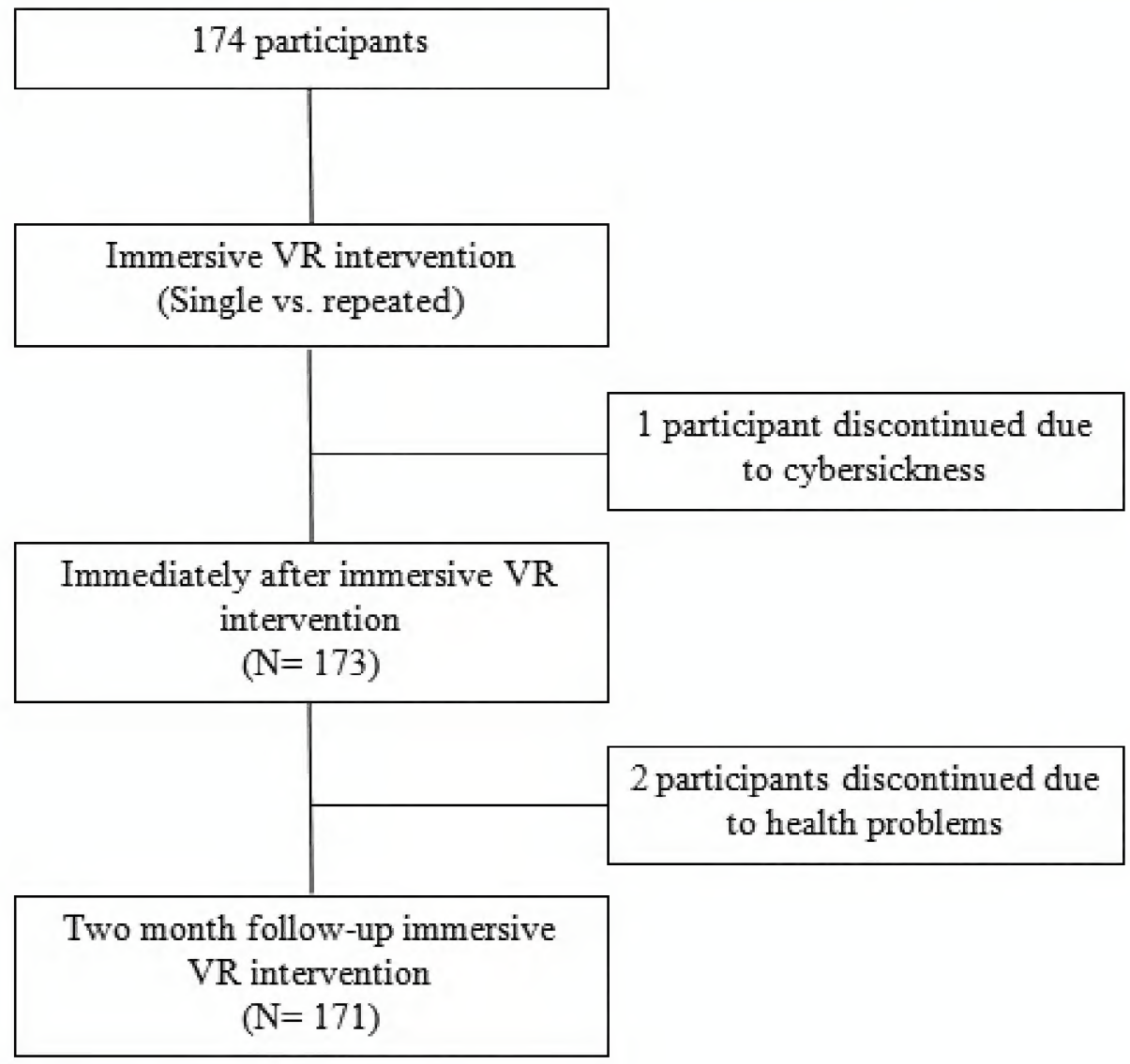
174 participants
Immersive VR intervention
(Single vs. repeated)
1 participant discontinued due to cybersickness
Immediately after immersive VR intervention
(N= 173)
2 participants discontinued due to health problems
Two month follow-up immersive VR intervention
(N= 171)

Figure 2. Study design diagram.

Table 2. Results of confirmatory factorial analysis.

Items	Composite reliability	Average variance extracted
Environmental awareness	0.923	0.724
Pro-conservation behavioral intention	0.884	0.643
Love and care for nature	0.945	0.552

Hypotheses testing

To test the research hypotheses H1 and H2, two mixed ANOVA analyses were performed. Exposure type to immersive VR (single vs. repeated, coded 0 and 1 respectively) was included as a between-subjects factor, while time (immediately after exposure vs. two months later) was included as a within-subjects factor. The results of the first analysis (Table 3) revealed a significant main effect of exposure type to immersive VR depicting degraded nature scenes. Participants exposed repeatedly reported significantly higher levels of environmental awareness than those exposed only once ($Mean_{Repeated\ exposure}$ = 4.70 vs. $Mean_{Single\ exposure}$ = 3.59; F = 46.696, p < 0.001, Eta^2 = 0.287). A main effect of time was also observed, showing an overall decrease in environmental awareness two-months after exposure compared to measurements taken immediately after the experience ($Mean_{Immediately\ after\ VR\ intervention}$ = 4.53 vs. $Mean_{Two\ months\ after\ VR\ intervention}$ = 3.75; F = 51.731, p < 0.001, Eta^2 = 0.308). In addition, a significant interaction between type of exposure (single vs. repeated) and time (immediately after vs. two months after VR intervention) was observed (F = 10.152, p < 0.01, Eta^2 = 0.080). To explore this interaction, paired t-tests were performed separately for each group. The results, presented in Table 3, show that a significant decrease in environmental awareness over time was observed only in the single-exposure group ($Mean_{Immediately\ after\ Single\ VR\ exposure}$ = 4.15 vs. $Mean_{Two\ months\ after\ Single\ VR\ exposure}$ = 3.03, t = 6.025, p < 0.001), while no significant variation was found in the repeated-exposure group (t = 1.871, p > 0.05). The environmental awareness score measured two months after repeated exposure to immersive VR remains higher than that observed two months after a single exposure ($Mean_{Two\ months\ after\ Repeated\ VR\ exposure}$ = 4.48, vs. $Mean_{Two\ months\ after\ Single\ VR\ exposure}$ = 3.03), supporting hypothesis H1. These results suggest that participants exposed repeatedly to immersive VR depicting degraded nature scenes show higher levels of environmental

Table 3. Results of mixed-ANOVA and paired samples t-test.

Mixed ANOVA											
			Dependent variables								
			Environmental awareness (H1)					**Pro-conservation behavioral intention (H2)**			
			Mean	**Standard deviation**	**F – statistic**	**p-Value**	**Eta – squared**	**Mean**	**F – statistic**	**P-Value**	**Eta squared**	**Standard deviation**
Exposure type	Single (N=87)		3.59	1.201	46.696	0.000	0.287	3.55	5.287	0.023	0.044	1.231
	Repeated (N=84)		4.70	1.01				3.94				1.129
Time	Immediately after exposure		4.53	1.005	51.731	0.000	0.308	3.98	11.119	0.001	0.087	1.132
	Two-months after exposure		3.75	1.189				3.51				1.259
Type of exposure * Time	Immediately after exposure	Single	4.15	1.160	10.152	0.002	0.080	3.88	1.592	0.210	0.014	1.155
		Repeated	4.91	0.995				4.09				1.027
	Two-months after exposure	Single	3.03	1.242				3.23				1.308
		Repeated	4.48	1.025				3.79				1.232

Paired samples t-test				
		Environmental awareness		
Exposure	**Time**	**Mean**	**Student's t**	**p-Value**
Single (n=87)	Immediately after exposure	4.15	6.025	0.000
	Two-months after exposure	3.03		
Repeated (n=84)	Immediately after exposure	4.91	1.871	0.064
	Two-months after exposure	4.48		

awareness and greater stability in these levels two months after the experience, unlike those exposed only once.

The results of the second analysis (Table 3) revealed a significant main effect of exposure type to immersive VR. Participants exposed repeatedly reported significantly higher levels of pro-conservation behavioral intention than those exposed only once ($M_{Repeated\ exposure}$ = 3.94 vs. $Mean_{Single\ exposure}$ = 3.55; F = 5.287, $p < 0.05$, $Eta^2 = 0.044$). A main effect of time was also observed, showing an overall decrease in pro-conservation behavioral intention two-months after exposure compared to measurements taken immediately after the experience ($M_{Immediately\ after\ VR\ intervention}$ = 3.98 vs. $M_{Two\ months\ after\ VR\ intervention}$ = 3.51; F = 11.119, $p < 0.01$, $Eta^2 = 0.087$). However, there was no significant interaction between exposure type (single vs. repeated) and time (immediately after VR intervention vs. two months later) on pro-conservation behavioral intention (F = 1.592, $p > 0.05$, $Eta^2 = 0.014$). In other words, although participants exposed repeatedly report higher conservation intentions, the temporal trajectory of these intentions was similar for both groups. Therefore, H2 was not proven.

In order to test research hypotheses H3 and H4, moderated mediation analysis were conducted using macro PROCESS, model 14, with 5000 bootstrap (Hayes 2018). The results (Fig. 3) indicate that exposure type (single vs. repeated) to immersive VR is positively and significantly associated with levels of environmental awareness reported two months after exposure (β = 0.47; $p < 0.001$, 95%CI = 0.25; 0.69), suggesting that participants repeatedly exposed to immersive experience present higher levels of environmental awareness than those exposed only once. Environmental awareness, in turn, positively influences pro-conservation behavioral intention (β = 0.28; $p < 0.001$, 95%CI = 0.15; 0.41), supporting hypothesis H3. However, the direct relationship between exposure type (single vs. repeated) and pro-conservation behavioral intention, measured after two months, is not significant (β = 0.06; $p > 0.05$, 95%CI = -0.07; 0.19), while the indirect relationship through environmental awareness is significant (β = 0.21; $p < 0.01$, 95%CI = 0.09; 0.33). These results indicate a full mediation of environmental awareness in the relationship between exposure type (single vs. repeated) and pro-conservation behavioral intention. Furthermore, analyses reveal that love and care for nature significantly and positively moderate the relationship between environmental awareness and pro-conservation behavioral intention (Interaction: M*W = 0.19; $p < 0.01$, 95%CI = 0.08; 0.30). This M*W interaction represents the combined effect of the mediator variable “M” (environmental awareness) and the moderator variable “W” (love and care for nature) on

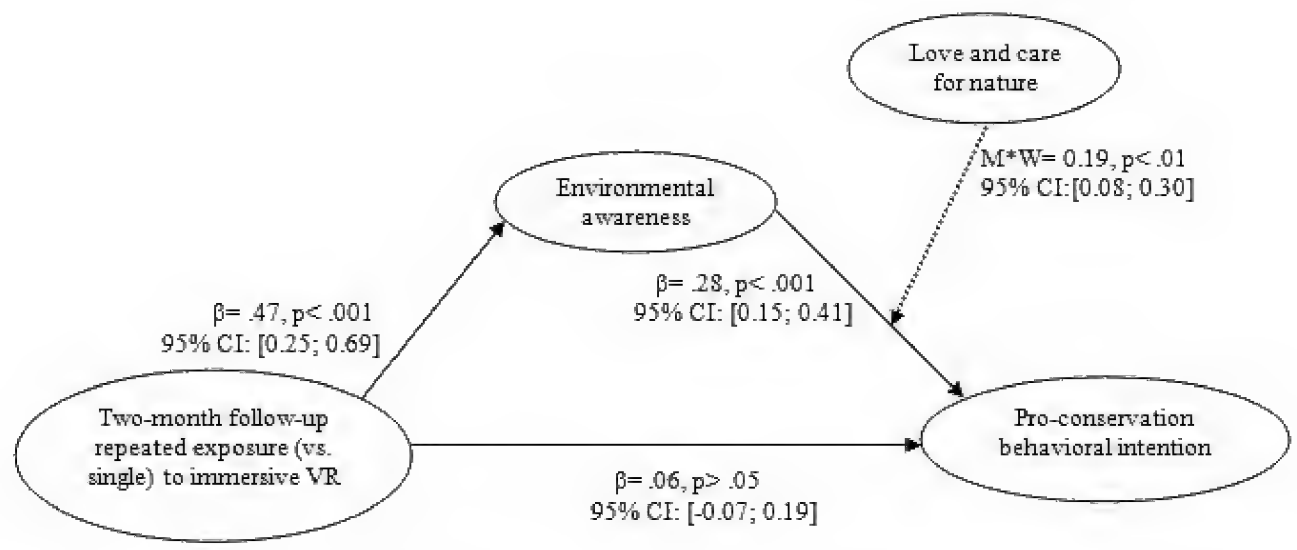

Figure 3. Moderated mediation analysis.

the dependent variable (pro-conservation behavioral intention), indicating that the strength of the relationship between awareness and conservation behaviors varies according to the level of love and care for nature. These results support hypothesis H4. In other words, the more individuals feel a strong love and care for nature, the stronger the relationship between their environmental awareness and their intention to adopt pro-conservation behaviors. These results suggest that affective dispositions towards nature play an essential amplifying role in transforming environmental awareness into pro-environmental intention.

Discussion

The results of this study show that, in the long term, participants repeatedly exposed to immersive VR depicting degraded nature scenes report higher levels of environmental awareness than those exposed only once. This observation is consistent with the findings of educational and training studies, such as those by Pande et al. (2021) and Lukander et al. (2025), which indicate that immersive VR is not limited to immediate effects on engagement or motivation, but can also promote long-term knowledge retention and behavior adoption. Our results are also consistent with some observations in the mental health literature, particularly those of Huang and Yang (2022) and Huang et al. (2025), which show that, without additional sessions, the cognitive or behavioral effects of VR tend to diminish over time. Thus, the absence of a significant decrease in environmental awareness scores in the group exposed to repeated sessions suggests that repeated exposure may be associated with greater stability in levels of environmental awareness over time. These observations shed further light on the potential contribution of immersive VR: they suggest that repeated interventions could promote the persistence of environmental awareness levels and highlight the value of designing repeated immersive experiences. Nevertheless, it is important to note a major limitation of the study: no pre-test measurements were taken, which prevents consideration of interpersonal differences in environmental awareness prior to exposure to immersive VR. Consequently, the results should be interpreted as differences observed after the intervention, rather than as direct causal effects. Thus, it is possible that some participants began the study with a higher level of environmental awareness, which could partly explain the stability observed in their awareness levels. This unmeasured initial variation could influence the interpretation of the results, suggesting the need for a pre-test in future research to better control for these interpersonal differences and thus refine the interpretation of the effects of repeated exposure.

The results also show no significant difference between repeated exposure and a single exposure to immersive VR depicting degraded nature scenes, in terms of pro-conservation behavioral intention measured two months after experience. In other words, despite overall higher levels of intention among repeatedly exposed participants, the temporal trajectory of pro-conservation intention remains similar for both groups (single exposure and repeated exposure). A main effect of time was observed, revealing a general decrease in pro-conservation behavioral intention after two months, with no evidence that repetition altered this decline. These finding suggest that repeated exposure is not associated with greater stability of pro-conservation intentions over time. These results are consistent with previous studies, such as those of Huang and Yang

(2022) and Huang et al. (2025), which showed that the effects of immersive VR tend to diminish over time in the absence of novel stimulation, suggesting an ephemeral nature of long-term effects. However, they contrast with the study by Lukander et al. (2025), in which exposure to immersive VR produced lasting effects on behavior. Finally, contrary to the observations of Ahn et al. (2014) concerning environmental behaviors, the absence of a significant difference in our study suggests that repeated exposure does not modify the temporal dynamics of pro-conservation behavioral intentions. These findings highlight that the persistence of pro-conservation behavioral intentions may depend more on the quality of the experience and the emotional and motivational content of the intervention than on the simple frequency of exposure. Moreover, the lack of a significant difference between groups could be explained by several factors, including the characteristics of the sample and the potential for fatigue resulting from repeated exposure to the same message. Firstly, the sample is limited to students from a single country, which may partly explain the lack of significant differences between the groups. Indeed, students from the same socio-cultural background may share similar characteristics that reduce variations between groups, making it more difficult to detect significant differences. Additionally, factors such as educational level, environmental concerns or cultural habits could influence participants' responses (Nouri and Bouzaabia 2026), which may limit the variability of scores and hinder the ability to identify differences between groups. It would be appropriate to diversify the sample by including participants from different countries, age groups, socio-economic backgrounds and cultures. This would not only allow the robustness of the results to be tested across different populations, but also enable the conclusions to be generalized to larger samples. Furthermore, the absence of a significant difference between the intention levels of participants exposed repeatedly and those exposed only once could also be explained by message fatigue. During successive repetitions, participants may experience a decrease in emotional and cognitive receptivity to environmental content, thereby reducing the supplementary impact of subsequent exposures (So et al. 2017; Nouri and Bouzaabia 2026). This fatigue may result from overexposure to the message, leading to a form of habituation where the immersive stimulus becomes less engaging or less emotionally motivating (Lu 2022). To address this limitation, future research could explore content diversity or combine VR with other types of interventions, such as interactive elements or different formats, in order to maintain participants' engagement. Finally, the lack of a pre-test measure to assess interpersonal differences in pro-conservation intentions prior to the intervention prevents control of initial variations among participants. This shortcoming makes it impossible to determine precisely the effect of repeated exposure on intention, as certain initial variations may have influenced the results independently of the repeated exposure. Consequently, future research should include a pre-test in order to better control for these initial differences and isolate the direct impact of repeated exposure to immersive VR.

The results of this study also showed that environmental awareness positively influences pro-conservation behavioral intentions. This observation is consistent with previous research, which has demonstrated that environmental awareness promotes the adoption of pro-environmental behaviors. For example, Ari and Yilmaz (2017), Yang et al. (2021) and Lin et al. (2022) have shown that environmental awareness has a significant and positive influence on

pro-environmental intentions and/or behaviors. Similarly, Dornhoff et al. (2019) highlighted the specific effect of awareness of biodiversity loss on conservation behaviors. This study also indicated that the direct relationship between exposure type (single vs. repeated) and pro-conservation behavioral intention, measured after two months, was not significant, and that this relationship was entirely mediated by environmental awareness. These findings are consistent with previous research showing that immersive VR increases cognitive responses and mental engagement, but do not systematically lead to a significant direct effect on pro-environmental behaviors (Meijers et al. 2023; Nouri et al. 2025; Nouri and Bouzaabia 2025). These works suggest that, although immersive VR stimulates reflection and attention to environmental issues, it is not in itself a sufficient lever to directly influence pro-environmental intentions or behaviors. Consequently, in the long-term, the indirect relationship observed between exposure type and pro-conservation behavioral intention, through environmental awareness, appears to depend more on the experience's ability to foster the emergence of environmental awareness capable of guiding subsequent choices and behaviors, rather than on simple repetition of exposure.

Finally, the results show that love and care for nature positively moderate the effect of environmental awareness on pro-conservation behavioral intentions. In other words, individuals who feel strong love and care for nature are more likely to transform their environmental awareness into concrete intentions to act for conservation. This observation is consistent with the work of Mayer and Frantz (2004), who argue that people who feel they are an integral part of nature are less likely to harm it, as well as with that of Martin et al. (2020), who show that nature connectedness moderates the relationship between contact with nature and certain measures of pro-environmental behavior. Our study extends this work by demonstrating that love and care for nature also act as moderators, reinforcing the impact of environmental awareness on pro-conservation intentions, suggesting that positive emotions towards nature may play a key role in translating awareness into intentions to act.

Conclusion

Theoretically, this study makes a significant contribution to the literature on immersive VR and its potential in the field of nature conservation. It stands out for its originality, as to our knowledge, it is one of the first studies to examine the short- and long-term differences in levels of environmental awareness and pro-conservation intention, depending on exposure type (repeated vs. single) to immersive VR experiences depicting degraded nature environments. Thus, unlike most previous studies (Pande et al. 2021; Huang et al. 2025; Lukander et al. 2025), which focus mainly on the effects of a single exposure to immersive VR, this study takes a longitudinal approach, assessing the differences immediately after exposure and then two months later, in order to examine the sustainability of the observed differences. This study also showed that, in the long-term, there is no direct relationship between exposure type (single vs. repeated) to immersive VR and pro-conservation behavioral intention, and that this relationship was entirely mediated by environmental awareness. This means that, in the long term, simply repeating immersive experiences is not enough to directly influence pro-conservation behavioral intention; rather, it is the ability of immer-

sive VR to strengthen environmental awareness that is the main lever. These results suggest that the effectiveness of immersive VR depends less on the frequency of exposure itself than on the cognitive processes it activates, in particular awareness of environmental issues, and that the success of repeated immersive VR experiences depends on their ability to mobilize and structure this awareness to promote pro-conservation behavioral intentions. Finally, the integration of love and care for nature as moderators represents a valuable conceptual advancement. It provides further understanding of the conditions under which environmental awareness translates into pro-conservation behavioral intentions, highlighting the amplifying role of emotions towards nature. These results highlight the importance of emotional dimensions in consolidating the long-term effects of immersive VR on pro-environmental engagement and suggest that the effectiveness of immersive interventions depends not only on raising environmental awareness, but also on the feelings of love and care that individuals have for nature.

From a managerial perspective, this study provides key guidance for environmental communication professionals, NGOs, public institutions and companies engaged in promoting nature conservation. Immersive interventions could be used, for example, in educational programs, environmental awareness campaigns or corporate training on sustainable development, targeting different audiences such as students, the general public or environmental professionals. First, repeated exposure is not simply redundant: it can be a strategic lever for strengthening environmental awareness. Designers and intervention managers are encouraged to incorporate repetition into the planning of their immersive devices, whether through interactive modules spread out over time or immersive campaigns in several phases. This approach not only facilitates technological acceptability, but can also maintain and consolidate environmental awareness over the long term, thereby reinforcing the impact of the environmental messages disseminated. Moreover, it is crucial to develop immersive VR experiences focused on degraded natural environments, directly linked to conservation issues. These simulations must realistically and vividly represent the concrete consequences of human activities on ecosystems in order to strengthen individuals' environmental awareness. By fully exploiting the immersive potential of VR, such an approach can not only deepen this awareness, but also heighten the sense of urgency and encourage responsible and proactive behavior, thereby making a concrete contribution to the protection and restoration of natural habitats. In practice, these immersive devices can thus serve as an operational tool for conservation initiatives, engaging individuals in an interactive and memorable way and reinforcing the effectiveness of environmental campaigns among audiences directly involved or targeted for conservation. Furthermore, immersive devices should be designed to stimulate reflection on environmental issues and facilitate understanding of the consequences of human behavior, for example through interactive modules, narrative scenarios or guided activities. This approach can effectively transform cognitive awareness into sustainable behavioral intentions, thereby maximizing the impact of immersive interventions. Finally, the results indicate that the effectiveness of immersive VR depends not only on raising environmental awareness, but also on the intensity of love and care that individuals feel for nature. To maximize the impact of immersive VR devices, conservation and environmental commu-

nication professionals should segment their audiences according to the level of these affective feelings. For participants who have high feelings of love and care for nature, interventions can focus on narratives or testimonials that celebrate pro-nature behaviors, reinforcing the sense of pride and legitimacy of their engagement, and on positive feedback regarding their choices or actions, even in virtual contexts, to support their intrinsic motivation. For those with low feelings of love and care for nature, it is crucial to incorporate elements aimed at developing these emotions by exposing participants to the negative consequences of human activities on nature and ecosystems, illustrating direct impacts such as pollution, deforestation, biodiversity loss, or habitat destruction. For those with weak feelings of love and respect for nature, it is crucial to incorporate elements aimed at developing these emotions by exposing participants to the negative consequences of human activities on nature and ecosystems, illustrating direct impacts such as pollution, deforestation, biodiversity loss, and habitat destruction. These elements can be integrated into immersive, interactive simulations, and narratives that recount the deterioration of ecosystems and the efforts needed to protect them, allowing participants to concretely visualize the effects of their choices and strengthen their awareness of human impact. This approach makes it possible to more effectively transform environmental awareness into sustainable pro-conservation behaviors.

References

Ahn SJG, Bailenson JN, Park D (2014) Short-and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. Computers in Human Behavior 39: 235–245. https://doi.org/10.1016/j.chb.2014.07.025

Ari E, Yilmaz V (2017) Effects of environmental illiteracy and environmental awareness among middle school students on environmental behavior. Environment, Development and Sustainability 19(5): 1779–1793. https://doi.org/10.1007/s10668-016-9826-3

Bratman GN, Anderson CB, Berman MG, Cochran B, De Vries S, Flanders J, Daily GC (2019) Nature and mental health: An ecosystem service perspective. Science Advances 5(7): eaax0903. https://doi.org/10.1126/sciadv.aax0903

Breves P, Heber V (2020) Into the wild: the effects of 360° immersive nature videos on feelings of commitment to the environment. Environmental Communication 14(3): 332–346. https://doi.org/10.1080/17524032.2019.1665566

Dornhoff M, Sothmann JN, Fiebelkorn F, Menzel S (2019) Nature relatedness and environmental concern of young people in Ecuador and Germany. Frontiers in Psychology 10: e453. https://doi.org/10.3389/fpsyg.2019.00453

Fornell C, Larcker DF (1981) Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 18(1): 39–50. https://doi.org/10.1177/002224378101800104

Frantz C, Mayer FS, Norton C, Rock M (2005) There is no "I" in nature: The influence of self-awareness on connectedness to nature. Journal of Environmental Psychology 25(4): 427–436. https://doi.org/10.1016/j.jenvp.2005.10.002

Frechette C, Diasio S, Luckett M, Trocchia PJ, Natali S (2023) Immersive technology as a social marketing tool: Exploring the impact of 360-video and virtual reality on intent to help and attitudes toward the homeless. Social Marketing Quarterly 29(1): 45–66. https://doi.org/10.1177/15245004221150796

Hair JF, Black WC, Babin BJ, Anderson RE, Tatham RL (2010) SEM: An introduction. Multivariate Data Analysis: A Global Perspective 5(6): 629–686.

Hayes AF (2018) Partial, conditional, and moderated moderated mediation: Quantification, inference, and interpretation. Communication Monographs 85(1): 4–40. https://doi.org/10.1080/03637751.2017.1352100

Huang LC, Yang YH (2022) The long-term effects of immersive virtual reality reminiscence in people with dementia: Longitudinal observational study. JMIR Serious Games 10(3): e36720. https://doi.org/10.2196/36720

Huang LC, Chien CF, Yang YH (2025) Exploring the immediate and long-term effects of immersive virtual reality on behavioral and psychological symptoms of dementia and caregiver burden: Longitudinal observational study. JMIR Serious Games 13(1): e73044. https://doi.org/10.2196/73044

Ibanez L, Roussel S (2022) The impact of nature video exposure on pro-environmental behavior: An experimental investigation. PLoS ONE 17(11): e0275806. https://doi.org/10.1371/journal.pone.0275806

Jacobs MH, Harms M (2014) Influence of interpretation on conservation intentions of whale tourists. Tourism Management 42: 123–131. https://doi.org/10.1016/j.tourman.2013.11.009

Kandaurova M, Lee SHM (2019) The effects of virtual reality (VR) on charitable giving: The role of empathy, guilt, responsibility, and social exclusion. Journal of Business Research 100: 571–580. https://doi.org/10.1016/j.jbusres.2018.10.027

Klein SA, Hilbig BE (2018) How virtual nature experiences can promote pro-environmental behavior. Journal of Environmental Psychology 60: 41–47. https://doi.org/10.1016/j.jenvp.2018.10.001

Kleinlogel EP, Mast MS, Renier LA, Bachmann M, Brosch T (2023) Immersive virtual reality helps to promote pro-environmental norms, attitudes and behavioural strategies. Cleaner and Responsible Consumption 8: e100105. https://doi.org/10.1016/j.clrc.2023.100105

Kosta AD, Keramitsoglou KM, Tsagarakis KP (2022) Exploring the effect of environmental programs on primary school pupils' knowledge and connectedness toward nature. SAGE Open 12(4). https://doi.org/10.1177/21582440221140288

Lange F, Truyens M (2022) Mixed evidence for the effect of virtual nature exposure on effortful pro-environmental behavior. Journal of Environmental Psychology 81: e101803. https://doi.org/10.1016/j.jenvp.2022.101803

LaViola JJ (2000) A discussion of cybersickness in virtual environments. ACM SIGCHI Bulletin 32(1): 47–56. https://doi.org/10.1145/333329.333344

Lin MT, Zhu D, Liu C, Kim PB (2022) A systematic review of empirical studies of pro-environmental behavior in hospitality and tourism contexts. International Journal of Contemporary Hospitality Management 34(11): 3982–4006. https://doi.org/10.1108/IJCHM-12-2021-1478

Lu H (2022) The role of repeated exposure and message fatigue in influencing willingness to help polar bears and support climate change mitigation. Science Communication 44(4): 475–493. https://doi.org/10.1177/10755470221105068

Lukander K, Lehikko A, Nykänen M, Lantto E, Uusitalo J, Ruokamo H (2025) Short and long-term effects of interactivity in immersive virtual reality training for occupational safety. Computers in Human Behavior Reports 20: e100809. https://doi.org/10.1016/j.chbr.2025.100809

Martin L, White MP, Hunt A, Richardson M, Pahl S, Burt J (2020) Nature contact, nature connectedness and associations with health, wellbeing and pro-environmen-

tal behaviours. Journal of Environmental Psychology 68: e101389. https://doi.org/10.1016/j.jenvp.2020.101389

Mayer FS, Frantz CM (2004) The connectedness to nature scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology 24(4): 503–515. https://doi.org/10.1016/j.jenvp.2004.10.001

Mayer FS, Frantz CM, Bruehlman-Senecal E, Dolliver K (2009) Why is nature beneficial? The role of connectedness to nature. Environment and Behavior 41(5): 607–643. https://doi.org/10.1177/0013916508319745

Meijers MH, Torfadóttir RH, Wonneberger A, Maslowska E (2023) Experiencing climate change virtually: The effects of virtual reality on climate change related cognitions, emotions, and behavior. Environmental Communication 17(6): 581-601. https://doi.org/10.1080/17524032.2023.2229043

Nisbet EK, Zelenski JM, Murphy SA (2009) The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. Environment and Behavior 41(5): 715–740. https://doi.org/10.1177/0013916508318748

Nouri I, Bouzaabia R (2025) Impact of immersive virtual reality on environmental mental imagery, climate risk perception and attitudes towards mitigation behaviors. European Journal of Sustainable Development Research 9(4): em0331. https://doi.org/10.29333/ejosdr/16833

Nouri I, Bouzaabia R (2026) Repeated exposure to immersive virtual reality: A lever for biodiversity conservation? Technological Sustainability: 1–17. https://doi.org/10.1108/TECHS-10-2025-0212

Nouri I, Zorgati H, Bouzaabia R (2025) The impact of immersive 360° video on environmental awareness and attitude toward climate change: The moderating role of cybersickness. Journal of Social Marketing 15(2/3): 175–194. https://doi.org/10.1108/JSOCM-09-2023-0219

Otto S, Pensini P (2017) Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. Global Environmental Change 47: 88–94. https://doi.org/10.1016/j.gloenvcha.2017.09.009

Palmisano S, Constable R (2022) Reductions in sickness with repeated exposure to HMD-based virtual reality appear to be game-specific. Virtual Reality 26(4): 1373–1389. https://doi.org/10.1007/s10055-022-00634-6

Pande P, Thit A, Sørensen AE, Mojsoska B, Moeller ME, Jepsen PM (2021) Long-term effectiveness of immersive VR simulations in undergraduate science learning: Lessons from a media-comparison study. Research in Learning Technology 29. https://doi.org/10.25304/rlt.v29.2482

Perkins HE (2010) Measuring love and care for nature. Journal of Environmental Psychology 30(4): 455–463. https://doi.org/10.1016/j.jenvp.2010.05.004

Plechatá A, Morton T, Perez-Cueto FJ, Makransky G (2022) A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change. Scientific Reports 12(1): e14315. https://doi.org/10.1038/s41598-022-18241-5

Ripple WJ, Wolf C, Newsome TM, Galetti M, Alamgir M, Crist E, 15364 scientist signatories from 184 countries (2017) World scientists' warning to humanity: A second notice. BioScience 67(12): 1026–1028. https://doi.org/10.1093/biosci/bix125

Slater M (2018) Immersion and the illusion of presence in virtual reality. British Journal of Psychology 109(3): 431–433. https://doi.org/10.1111/bjop.12305

So J, Kim S, Cohen H (2017) Message fatigue: Conceptual definition, operationalization, and correlates. Communication Monographs 84(1): 5–29. https://doi.org/10.1080/03637751.2016.1250429

Soga M, Gaston KJ (2016) Extinction of experience: The loss of human–nature interactions. Frontiers in Ecology and the Environment 14(2): 94–101. https://doi.org/10.1002/fee.1225

Soga M, Gaston KJ (2024) Do people who experience more nature act more to protect it? A meta-analysis. Biological Conservation 289: e110417. https://doi.org/10.1016/j.biocon.2023.110417

Spangenberger P, Freytag SC, Geiger SM (2024) Embodying nature in immersive virtual reality: Are multisensory stimuli vital to affect nature connectedness and pro-environmental behaviour? Computers & Education 212: e104964. https://doi.org/10.1016/j.compedu.2023.104964

Straka TM, Glahe C, Dietrich U, Bui M, Kowarik I (2025) From nature experience to pro-conservation action: How generational amnesia and declining nature-relatedness shape behaviour intentions of adolescents and adults. Ambio 54: 1165–1184. https://doi.org/10.1007/s13280-025-02135-7

Thoma SP, Hartmann M, Christen J, Mayer B, Mast FW, Weibel D (2023) Increasing awareness of climate change with immersive virtual reality. Frontiers in Virtual Reality 4: e897034. https://doi.org/10.3389/frvir.2023.897034

Trivedi RH, Patel JD, Acharya N (2018) Causality analysis of media influence on environmental attitude, intention and behaviors leading to green purchasing. Journal of Cleaner Production 196: 11–22. https://doi.org/10.1016/j.jclepro.2018.06.024

Trope Y, Liberman N (2010) Construal-level theory of psychological distance. Psychological Review 117(2): 440–463. https://doi.org/10.1037/a0018963

Waterworth JA, Waterworth EL, Riva G, Mantovani F (2015) Presence: Form, Content and Consciousness. Immersed in Media: Telepresence Theory, Measurement & Technology. Springer International Publishing, Cham, 35–58. https://doi.org/10.1007/978-3-319-10190-3_3

Whitburn J, Linklater WL, Milfont TL (2019) Exposure to urban nature and tree planting are related to pro-environmental behavior via connection to nature, the use of nature for psychological restoration, and environmental attitudes. Environment and Behavior 51(7): 787–810. https://doi.org/10.1177/0013916517751009

Wieland DA, Ivens BS, Kutschma E, Rauschnabel PA (2024) Augmented and virtual reality in managing B2B customer experiences. Industrial Marketing Management 119: 193–205. https://doi.org/10.1016/j.indmarman.2024.04.007

Yang MX, Tang X, Cheung ML, Zhang Y (2021) An institutional perspective on consumers' environmental awareness and pro-environmental behavioral intention: Evidence from 39 countries. Business Strategy and the Environment 30(1): 566–575. https://doi.org/10.1002/bse.2638

Yu T, Hao X, Lange F (2023) The effects of virtual nature exposure on pro-environmental behaviour. International Journal of Psychology 59(1): 203–207. https://doi.org/10.1002/ijop.12949

Zelenski JM, Dopko RL, Capaldi CA (2015) Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behavior. Journal of Environmental Psychology 42: 24–31. https://doi.org/10.1016/j.jenvp.2015.01.005

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

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Author contributions

Imed Nouri: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Khouloud Chaabane: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. Rym Bouzaabia: Writing – review & editing, Visualization, Validation, Supervision.

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Data availability

All of the data that support the findings of this study are available in the main text.